

Identification and Quantitation of Microparticles in Solid Materials

by D. R. Bowes*

Variation in the precise conditions of geological formation may produce variations in the exact composition of asbestos minerals of a particular class, and thus in their biological interactions. Examples are given of differences in O^{18}/O^{16} ratios, TiO_2 content, lattice substitutions, substitution of Al (III) for Si (IV) and attachments to spare hydrostatic charges.

Some the geological, geochemical, and mineralogical factors to be considered in attempts to "type" asbestos minerals for comparison with mineral particles extracted from biological tissue for identification and quantitation by electron microscopy and other techniques are summarized.

The crustal situation of many economically exploited asbestos bodies is in mobile belts associated with major oceanic-continental plate boundaries, for example the Appalachian belt. In this situation, ultrabasic masses are emplaced, and hydrothermal solution activity and metasomatism commonly accompanies metamorphism and deformation, one result being the development of chrysotile from the ultrabasic rocks. As the proportions of water derived from sediments, igneous intrusions and meteoric sources may vary, so the proportions of O^{16} and O^{18} may also vary both from one asbestos body to another and within a single body.

Similar looking amphibole-rich rocks (amphibolites and hornblende schists) may show significant differences in major and trace element chemistry indicative of derivation by metamorphism of either igneous or sedimentary rocks, as in the case of bedrock of New York City (Fig. 1). Here, differences in TiO_2 proportions

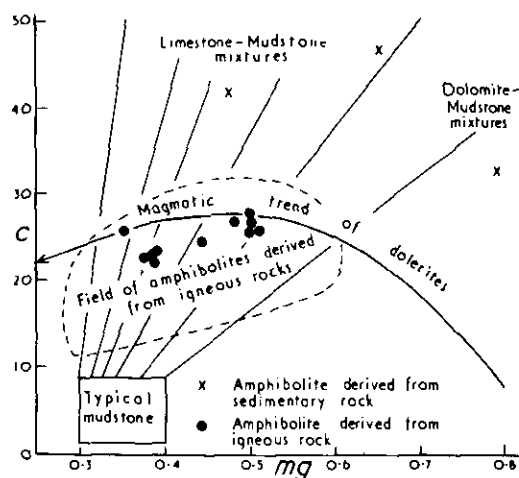


FIGURE 1. Plot of Niggli values mg against c (related to cation percentages of magnesium and calcium, respectively) for amphibolites of Manhattan Formation, New York City. After Bowes and Langer (1).

(by a factor of 12) and in the proportions of other constituents portend differences in surface properties and response to biological fluids of amphiboles inhaled and ingested by tunnel construction workers.

Many amphibole-bearing rocks show evidence of more than one phase of amphibole growth. Differences in temperature and pressure conditions are reflected by varying chemistry due to lattice substitutions and often by shape characteristics such as length/breadth ratio.

*Department of Geology, The University of Glasgow, Glasgow, Scotland.

Amphiboles show a very wide range of compositions, resulting from lattice substitution. A general formula is $X_{2-3}Y_5Z_8O_{22}(OH,F)_2$, where X is commonly Ca, Na, or Mn; Y is commonly Mg, Fe, Ti, Al, or Mn; Z is mainly Si, but replaceable up to about 25% by trivalent ions with a radius up to 0.67 Å, particularly Al.

The amphibole structure is based on a Si_4O_{11} double chain unit (Fig. 2). Two Si_4O_{11} double chain units sandwich the Y ions (M_1 , M_2 , and M_3 in Fig. 3) between them. The X ions, up to two in number, occupy the M_4 position; any in excess of two occupy the A position. The extent of substitution in the X and Y sites is shown by the compositions of two amphibole asbestos minerals (3):

Crocidolite:

$Na_{1.35}K_{0.13}Ca_{0.17}Fe(II)_{0.49}Mg_{2.08}Fe(III)_{1.56}Al_{0.05}(Si_{7.94}Al_{0.06})O_{22}(OH)_2$

Tremolite:

$Ca_2.00Na_{0.03}Mg_{4.92}Fe(II)_{0.04}Fe(III)_{0.02}Al_{0.05}(Si_{7.81}Al_{0.19})O_{21.99}(OH)_2$

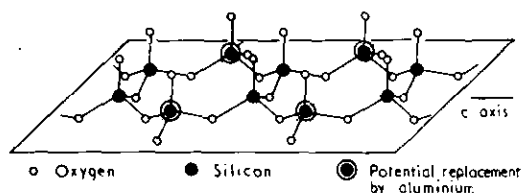


FIGURE 2. Perspective view of the $(Si_4O_{11})_n$ double chain which occurs in the structures of all amphiboles. After Deer et al. (2).

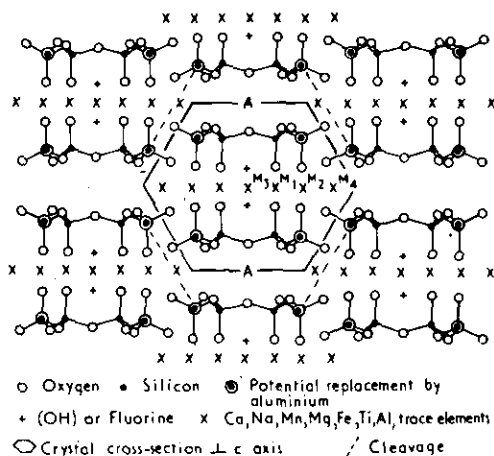


FIGURE 3. Projection on (001) in crocidolite showing atomic structure. Y ions occupy sites M_1 , M_2 , and M_3 ; X ions occupy site M_4 . Any X ions in excess of two per formula occupy the A site. After Whittaker (3).

Fields of composition of the amphibole asbestos minerals, viz. anthophyllite, amosite, crocidolite, tremolite (-actinolite) are represented in Figure 4.

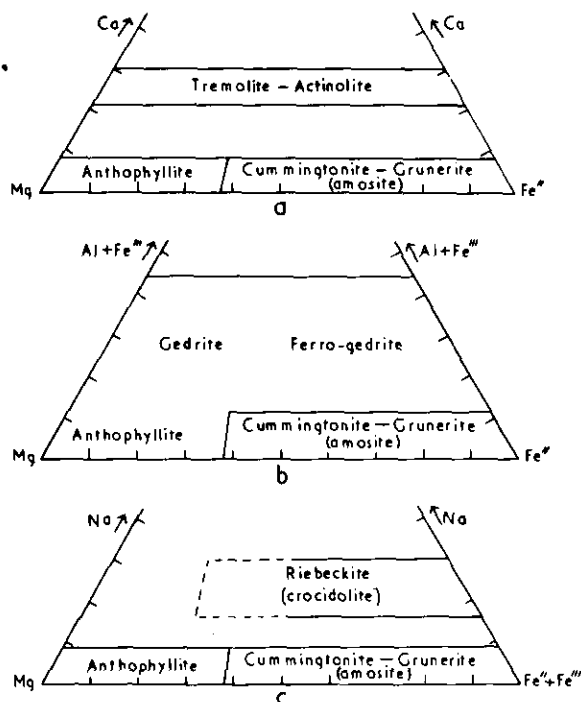


FIGURE 4. Diagrams of three component composition fields for the amphiboles, including the amphibole asbestos minerals anthophyllite, amosite, crocidolite, and tremolite (-actinolite): (a) Mg - Fe (II) - Ca field in the absence of trivalent elements and alkali metals; (b) Mg - Fe (II) - [Al + Fe (III)] field in the absence of calcium and the alkali metals; (c) Mg - [Fe (II) + Fe (III)] - Na field in the absence of calcium and aluminum. After Whittaker (3).

Substitution of Al (III) for Si (IV) in the Si_4O_{11} double chain unit is electrostatically balanced by Na^{+1} going into the A position. In addition the Si - Al substitution only occurs in certain of the Si sites which parallel the (110) cleavage plane (Figs. 2, 3). In this way the size of cleavage fragments, their length/breadth ratio and their surface properties may be changed.

In summation, variations in shape, size, surface properties, and chemical composition of amphibole asbestos minerals provide body fluids with a multichoice situation.

The final point is possibly esoteric, but possibly very practical. Silicate minerals have

regular and repeated Si=O units with substitutions of linking cations and a pattern of the substitution of Si (IV) by Al (III) in the basic unit. In the case of at least some silicates (clays), organic molecules (alcohols) adhere to their surfaces by utilizing spare hydrostatic charges. Is it possible, then, that minerals such as clays, asbestos minerals, talc, and micas act as templates for the initial message carriers (*4*), i.e., are silicate minerals with sheet and chain lattice structures the precursors of a genetic code?

REFERENCES

1. Bowes, D. R., and Langer, A. M. Hornblende schists in the Manhattan Formation, in *The Bronx*, New York: Discussion. *Bull. Geol. Soc. Amer.* **84**: 1483 (1973).
2. Deer, W. A., Howie, R. A., and Zussman, J. *Rock-forming Minerals*. Vol. 2. Chain Silicates. Longmans, London, 1963.
3. Whiteaker, E. J. W. The crystal chemistry of the amphiboles. *Acta Cryst.* **13**: 291 (1960).
4. Cairns-Smith, A. G. *The Life Puzzle: On Crystals and Organisms and On the Possibility of a Crystal as an Ancestor*. Oliver & Boyd, Edinburgh, 1971.